Paper

Optical-microwave transmission system with subcarrier multiplexing for industrial measurement systems

Jarosław Dawidczyk, Bogdan A. Galwas, Jerzy Skulski, Zenon Szczepaniak, Henryk Gruchała, and Sergey Malyshev

Abstract — We describe short-distance three-channel optical-microwave link with subcarrier multiplexing for transmission digital and/or analog data between different points of industrial measurement systems. The optical fiber link operates with Fabry-Perot laser at 1300 nm, multimode fiber and PIN photodiode receiver. From microwave point of view three carriers with frequencies 600 MHz, 800 MHz and 1000 MHz were chosen. The structure and main parameters of a link are reported and discussed.

Keywords* — *optical-microwave link, subcarrier multiplexing.

1. Introduction

The contemporary optical communication systems base on multichannel digital high-speed fiber transmission [1]. The driving force motivating the use of multichannel optical systems is the enormous bandwidth of optical fiber. To exploit of the fiber's terahertz bandwidth the wavelength-division multiplexing WDM is used typically. However, analog optical communications has some very appealing characteristics that make it a possible solution for some near – term general communications problems. These include CATV, video distribution, local area networks etc. In such case subcarrier multiplexing SCM seems to be the best solution of multichannel transmission problems [2, 3]. Many industrial measurements systems operate at extremely difficult conditions, with high level of industrial noise, disturbances and distortions. If a distance between sensors and a central controlling unit is long, than the transmission of measurement data arises to the great problem [4, 5]. Application of fiber transmission line could be very helpful and useful because of its natural immunity to electromagnetic interference. The properties of the fibre optic link can be measured with the use of the special photonic techniques [6].

2. Basic structure of optical-microwave transmission system with SCM

The essence of subcarrier multiplexing system is to take all the modulating, demodulating, multiplexing and demultiplexing functions and perform them electrically. The only optical functions that remain are: optical generation with semiconductor laser, optical transmission over an optical fiber and optical detection using a photodiode. Sometimes some passive optical elements could be used (splitters, couplers, etc.).

The schematic representation of a link is shown in Fig. 1. At the transmitter side of the link three streams of data are directed to the three microwave transmitters. The carrier frequencies of these transmitters are equal to 600 MHz, 800 MHz and 1000 MHz, respectively. The signals of carriers are modulated in different manner. The output signals are combined by multiplexer, next amplified and directed by driver to laser diode. The basic characteristics of multiplexer are shown in Fig. 2.

The transmitted optical signal is at first detected by photodiode at the receiver side of the link. Next, after amplification, demultiplexer directs the signal to three arms. Three different microwave receivers recover the transmitted data.

3. Optical link

Three main elements create an optical link: optical transmitter with laser semiconductor diode, multimode fiber and optical receiver with PIN photodiode.

The main device of transmitter is a laser package. The most fundamental component of a laser package is, of course, laser diode. An important auxiliary component is the photodiode sensing the laser power. The special optical power loop is used for stabilization a mean optical power of the laser.

More sophisticated laser packages include the thermoelectric cooler needed to keep the laser temperature constant and the thermistor used as a temperature sensor (Fig. 3). The developed cheep model of optical link uses Fabry-Perot 1300 nm laser diode HP-LST2825-T-FP with output optical power about 1.2 mW, but for more difficult industrial conditions of exploitation a laser package with thermoelectric cooler may be used.

On the basis of results published earlier [3] simple three-transistor driving circuit was developed. The bandwidth of the driving circuit is greater than 1200 MHz. The circuit includes power loop for stabilization an output optical power.

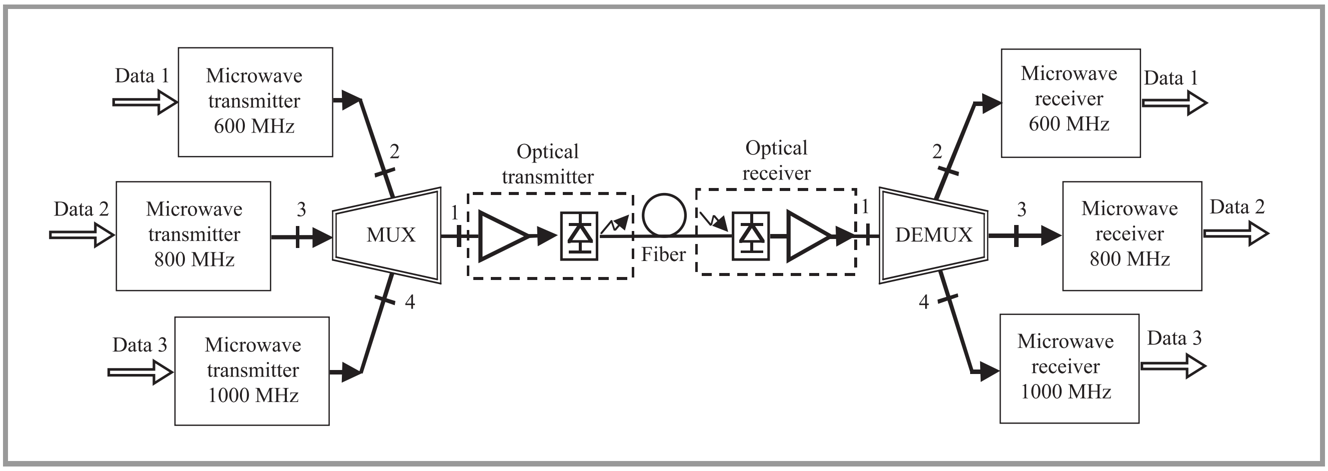


Fig. 1. Block diagram of optical-microwave transmission system.

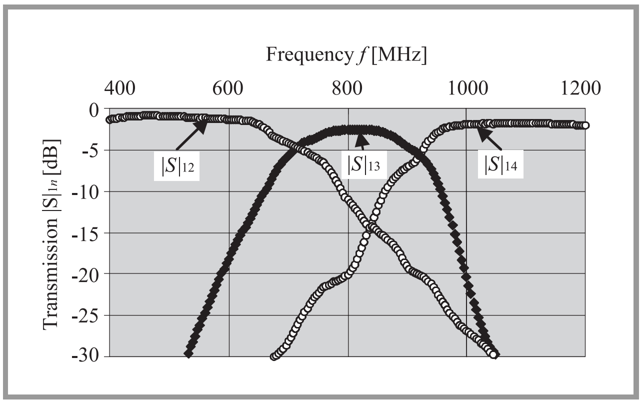


Fig. 2. Measured transmission between different arms of microwave multiplexer.

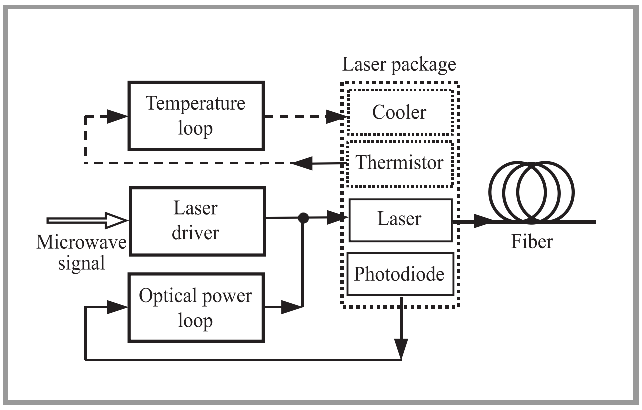


Fig. 3. Diagram of the laser driving circuit of optical transmitter.

Because the distance of transmission is expected to be below 1000 meters, a cheap multimode fiber has been used. For optical receiver a InP/InGaAs PIN FDD1003FC1[1] photodiode was used with a bandwidth better than 3.5 GHz and a responsivity of 1 A/W [7]. Low-noise wideband amplifier, design with special input matching circuit, first amplifies output signal from photodiode. The signal is next amplified by monolithic integrated amplifier (Fig. 4). The capacitance C_S effectively protects the preamplifier from the high DC component of the photocurrent. The 3 dB bandwidth of optical receiver is about 1.5 GHz.

[1]This type of photodiode has been developed by Institute of Electronics, National Academy of Sciences of Belarus, 22 Lagoiski Trakt, 220090, Minsk, Belarus.

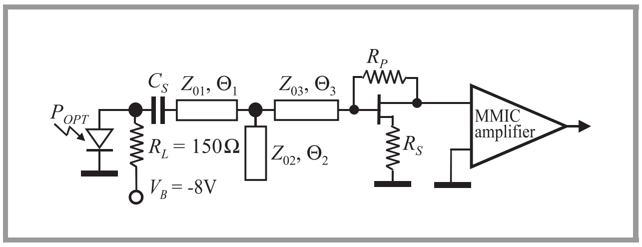


Fig. 4. Diagram of optical receiver with input matching circuit of the wideband low-noise transistor amplifier.

4. Microwave signal processing

The optical-microwave transmission system is able to transmit three different streams of data: one analog signal and two signals in digital form.

The microwave processing of the one of the digital signals is shown in diagram in Fig. 5. The frequency of carrier is equal to 800 MHz. The amplitude modulation has been used at the transmitter side. At the receiver side the input signal is exactly filtered, next amplified and mixed with local oscillator frequency, then amplified and detected.

Two other microwave links use process of a frequency modulation (Fig. 6). The link with frequency carrier equal to 600 MHz is able to transmit an analog signal. The input analog signal between +2 V $\ldots -2$ V gives the changes of VCO frequency 600 MHz ±30 MHz. Maximum of frequency deviation is equal to 30 MHz.

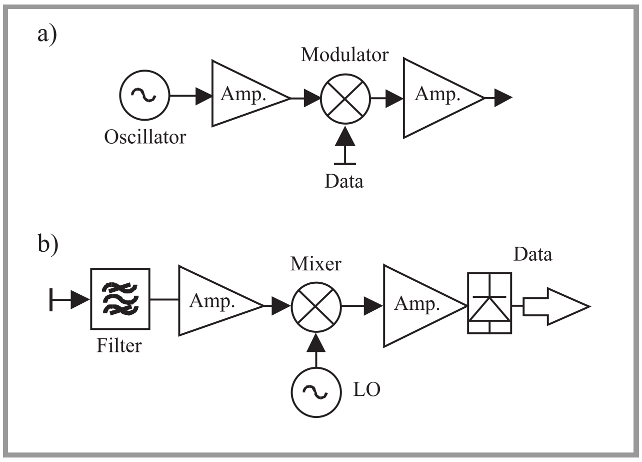


Fig. 5. Block diagram of microwave transmitter (a) and microwave receiver (b) for 800 MHz link with amplitude modulation.

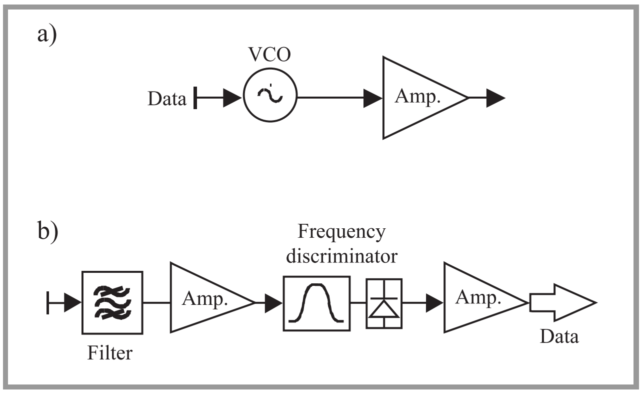


Fig. 6. Block diagram of microwave transmitter (a) and microwave receiver (b) for 600 MHz and 1000 MHz links with frequency modulation.

At the receiver side an input signal is filtered and next amplified. The frequency discriminator changes the frequency modulation to amplitude one. The detection and amplification complete the processing. The receiver filters together with demultiplexer selectivity give very good isolation between channels. The frequency responses of the channels are determined by the characteristics of receiver filters.
The second digital links uses 1000 MHz carrier frequency. This frequency is keying with deviation of 30 MHz. The block diagram of receiver is the same like in the case of analog one.

5. Conclusions

Multi-channels optical-microwave link with subcarrier multiplexing provides a unique set of advantages for telemetry industrial installations. The measured signals can be carry directly at RF and microwave frequencies over wide bands, with high dynamic range and without influence of industrial noise and disturbances. These capabilities allow telemetry electronics to be placed together with their operators, even when the sensors are hundred meters away.
In the nearest future full-duplex transmission system will be design. It will make possible to transmit data and orders in two directions, from operators to sensors also.

References

[1] L. Kazovsky, S. Benedetto, and A. Willner, *Optical Fiber Communication Systems*. Boston, London: Artech House, 1996, Chapt. 7.

[2] R. Olshansky, V. A. Lanziesera, and P. M. Hill, "Subcarrier multiplexed lightwave systems for broad band distribution", *IEEE J. Lightw. Technol.*, vol. 7, pp. 1329–1342, 1989.

[3] T. Berceli *et al.*, "Improvements in fiber-optic transmission of multicarrier TV signals", *IEEE Trans. MTT*, vol. 40, no. 8, pp. 910–914, 1992.

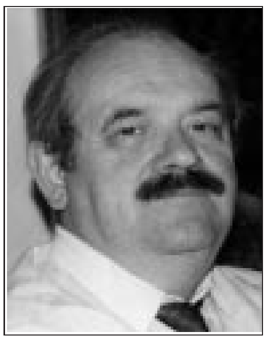
[4] J. Skulski, R. Perkowski, J. Piotrowski, and B. Galwas, "Mikrofalowy rezonatorowy czujnik do przemysłowych pomiarów stratnych materiałów dielektrycznych", in *Proc. Conf. COE'96*, Szczyrk, Poland, May 1996.

[5] B. Galwas, J. K. Piotrowski, and J. Skulski, "New type of microwave resonator sensors with waveguide below cut-off", in *Proc. Conf. Precis. Electromagn. Measur.*, Braunschweig, Germany, June 1996.

[6] J. Jasenek, O. Čermák, "Optical reflectometry with synthesized coherence function, in photonics, devices, and systems", *Proc. SPIE*, no. 4016, pp. 204–210, 2000.

[7] K. Piotrowski, B. A. Galwas, S. A. Malyshev, and V. F. Andrievski, "Investigation of InGaAs PIN photodiode for optical microwave mixing process", in *Proc. 12th Int. Microw. Conf. MIKON'98*, Cracow, Poland, May 1998.

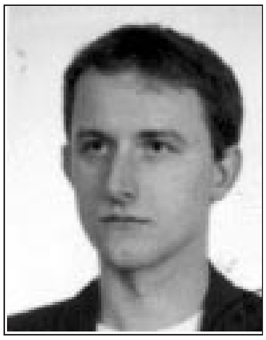
Jarosław Dawidczyk received the M.Sc. degree in microelectronics from Warsaw University of Technology (Poland) in 1998. Since 1998 he is a Ph.D. student at the Institute of Microelectronics and Optoelectronics, Warsaw University of Technology. His research interests include modelling of optical-microwave mixing processes and modelling of optical-microwave devices.
e-mail: j.dawidczyk@elka.pw.edu.pl
Institute of Microelectronics and Optoelectronics
Warsaw University of Technology
Nowowiejska st 15/19
00-665 Warsaw, Poland



Bogdan A. Galwas was born in Poland, on October 31, 1938. In 1962, he joined the Faculty of Electronics, Warsaw University as Lecturer. He received the M.Sc. degree in 1962, the Ph.D. degree in 1969, and the D.Sc. degree in 1976, all in electronic engineering from Warsaw University of Technology, Poland. In 1986 he was promoted to Full Professor. His current research interests are microwave electronics and photonics. He is the author of more than

120 scientific papers and 2 books in these areas. His main field of academic interest is connected with technology of education, continuing engineering education and open distance learning. He is a Chairman of the International Management Committee of the International Travelling Summer Schools '91, Member of IACEE '97 and Member of SEFI '97.
e-mail: galwas@imio.pw.edu.pl
Institute of Microelectronics and Optoelectronics
Warsaw University of Technology
Koszykowa st 75
00-662 Warsaw, Poland

Jerzy Skulski received the M.Sc. degree in microelectronics from Warsaw University of Technology (Poland) in 1970. Actually he is a Lecturer at the Institute of Microelectronics and Optoelectronics, Warsaw University of Technology. His research interests include microwave sensors, generators, amplifiers and microwave measurement systems.
e-mail: jskulski@imio.pw.edu.pl
Institute of Microelectronics and Optoelectronics
Warsaw University of Technology
Nowowiejska st 15/19
00-665 Warsaw, Poland



Zenon R. Szczepaniak received the M.Sc. degree in optoelectronics from Warsaw University of Technology (WUT), Poland in 1998. Since 1998 he is a Ph.D. student at the Microwave Devices Division at the Warsaw University of Technology. His research interests include optically-controlled microwave circuits, modelling of optical-microwave devices and systems for telecommunication.
e-mail: zenon.szczepaniak@elka.pw.edu.pl
Institute of Microelectronics and Optoelectronics
Warsaw University of Technology
Koszykowa st 75
00-662 Warsaw, Poland

Henryk Gruchała
Military Academy of Technology
Kaliskiego st 2
01-476 Warsaw, Poland

Sergey Malyshev – for biography, see this issue, p. 16.